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TR-2244-ENV

USER'S DATA PACKAGE (UDP) FOR OILY SLUDGE SEQUENCING BATCH REACTOR (SBR) TREATMENT SYSTEM

by

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14. ABSTRACT

The Department of Defense facilities generate thousands of tons of oily sludge annually. The Naval Facilities Engineering Service Center (NFESC) was tasked to conduct bench and pilot-scale testing of oily sludge biodegradation. In collaboration with PWC Pearl Harbor, NFESC designed, installed, and operated a 10,000-gallon sequencing batch reactor (SBR) for the on-site degradation of oily sludge. Test results demonstrate that on-site biological treatment is technically and economically feasible and that a sequencing batch reactor is easily assembled on site using off-the-shelf components and surplus tanks. The User's Data Package (UDP) addresses the criteria to qualify an SBR treatment system. The factors that need to be assessed prior to the procurement and installation of a SBR treatment system include economic feasibility, design considerations, regulatory requirements, sludge generation rates, sludge transporting requirements, and site applicability. This document also contains a sample economic analysis, sample statement of work (SOW), and applicable AutoCAD drawings. The time estimate for system installation from initial design to system operation is typically 20 months.

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EXECUTIVE SUMMARY

Department of Defense facilities generate thousands of tons of oily sludge annually. Naval Facilities Engineering Service Center (NFESC) was tasked to conduct bench and pilot-scale testing of oily sludge biodegradation. In collaboration with PWC Pearl Harbor, NFESC designed, installed, and operated a 10,000 gallon sequencing batch reactor (SBR) for the on-site degradation of oily sludge. Test results demonstrate that on-site biological treatment is technically and economically feasible and that a sequencing batch reactor is easily assembled on site using off-the-shelf components and surplus tanks. The User's Data Package (UDP) addresses the criteria to qualify an SBR treatment system. The factors that need to be assessed prior to the procurement and installation of a SBR treatment system include economic feasibility, design considerations, regulatory requirements, sludge generation rates, sludge transporting requirements, and site applicability. The UDP also contains a sample economic analysis, sample statement of work (SOW) and applicable AutoCAD drawings. The time estimate for system installation from initial design to system operation is typically 20 months.

ACKNOWLEDGEMENTS

We wish to thank the Naval Facilities Engineering Command and the Environmental Protection, Safety and Occupational Health Division (N45) of the Chief of Naval Operations for funding and sponsoring this project under the Pollution Abatement Ashore Program.

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The authors would also like to thank the following persons who each provided their own individual talents to the success of the project:

Dr. Fred Goetz, IPA at the University of California Santa Barbara; Mr. Jeff Heath, Branch Head, Pollution Prevention Technology Development Branch, Naval Facilities Engineering Service Center; Mr. Andy Del Collo, NAVFAC Environmental RTD&E Program Manager, Mr. Steve Christiansen, Department Supervisor, Environmental Division, Public Works Center Pearl Harbor; Mr. Allan Esaki, Division Supervisor, Environmental Division, Public Works Center Pearl Harbor; Mr. Dennis Chang, Division Supervisor, Environmental Division, Public Works Center Pearl Harbor; Mr. Andy Yee, BOWTS Supervisor, Environmental Division, Public Works Center Pearl Harbor; Mr. Randal Jones, President, Wastewater Resources Incorporated.

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1.0 INTRODUCTION

DoD facilities generate thousands of tons of oily sludge annually at industrial wastewater treatment plants, washracks, fuel depots, industrial operations, and maintenance facilities. Since this waste cannot be recycled or burned, it is drummed and landfilled. The cost to the Navy alone is in excess of $1.5M per year to dispose of oily waste from tank bottoms and the bilge oily wastewater treatment systems (BOWTS). Due to increasing costs, long term liability, and restrictions on landfill disposal, cost effective on-site treatment is a desirable option.

With support from NAVFAC, under the Navy's Pollution Abatement Ashore Program, the Naval Facilities Engineering Service Center (NFESC), Port Hueneme, California conducted bench and pilot-scale tests that demonstrated the potential for bioremediating oily sludge generated from Navy oily waste treatment plants. Research completed by NFESC shows that bacteria already present in and adapted to oily sludge from a variety of sources degrade sludge hydrocarbons within two weeks from 20,000 ppm to less than 100 ppm and render the sludge non-toxic. In addition, the concentrations of heavy metals (primarily zinc and copper) and total suspended solids in treated liquids and solids are well within discharge limits.

2.0 SYSTEM DESCRIPTION

In collaboration with Public Works Center (PWC) Pearl Harbor, NFESC designed, installed and successfully tested a pilot sequencing batch reactor (SBR) for the on-site degradation of oily sludge. The SBR system is installed on a concrete pad with secondary spill containment. Vacuum trucks can deliver oily sludge from sludge producing activities such as fuel tanks, pump stations, and oil/water separators. A schematic diagram of a typical bioreactor installation and associated components is shown in **Figure 1.** At the NAVSTA Pearl Harbor, sludge is pumped from delivery trucks into a receiving tank (T1) where it is diluted and run through a trash pump (P1) to produce a homogenous slurry. The trash pump is also used to transfer sludge to the reactor and can be used to periodically circulate sludge in the receiving tank. The receiving tank is aerated, using a high-pressure blower, to reduce the formation of sulfur compounds and keep the tank mixed.

The nominal design capacity of the reactor (SBR tank) is 15,000 to 20,000 gallons per month of diluted sludge, which corresponds to 3,000 to 4,000 gallons per month of raw sludge. Reactors are equipped with an aeration system, recirculation pump, thermocouple, level sensor and alarm, and sampling ports. Equipping the recirculation inlet with a spray head controls foaming in the reactor tank. The recirculation pump is plumbed so that a concentrated solution of nutrients (nitrogen, phosphorus, and commercial products that provide amino acids and vitamins) is pumped directly into the reactor. The nutrient concentration is proportional to the hydrocarbon concentration; at PWC Pearl Harbor it averages 0.004 pound of nutrients per pound of sludge. A pH controller is used to deliver sodium hydroxide to neutralize carboxyclic acids produced during initial degradation of the hydrocarbons and maintain a near neutral pH. The

production of these intermediates, which are surfactants, is also responsible for the foaming. As these compounds are degraded, foam formation decreases and the pH stabilizes at about 7.5. The skid mounted ultrafiltration (UF) modules are commercially available and are easily plumbed into the system. Systems are plumbed with copper, stainless steel, and PVC pipes. NFESC demonstrated at PWC Pearl that a complete bioreactor system could be assembled using off-the-shelf components.

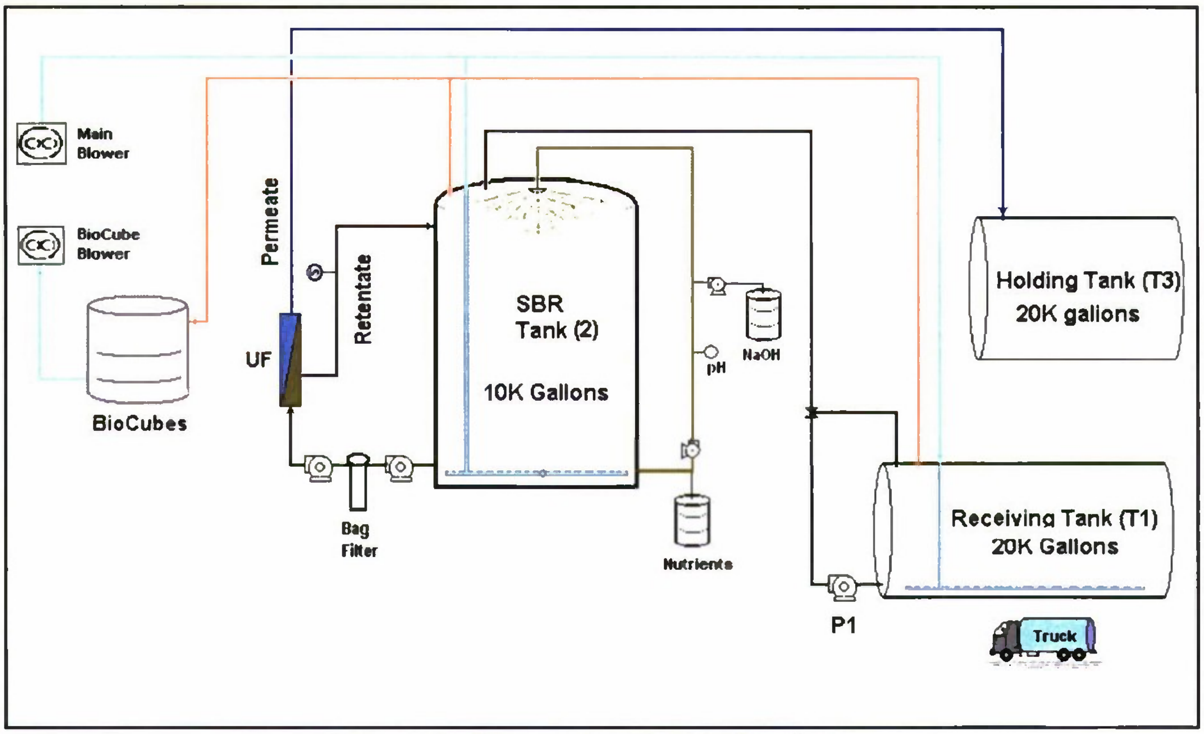


Figure 1. Sequencing Batch Reactor.
Schematic of a 10,000 gallon sequencing batch reactor and associated components. BioCubes are used to scrub the exhaust air. The ultrafiltration unit (UF) is used to recycle the biomass. A separate exhaust blower is used to capture air from the receiving tank and reactor. The main blower provides air to the reactor and receiving tank.

Although aerobic degradation does not produce odors, oily sludge may contain volatile odorous compounds. Thus, exhaust air from the reactor and processing tank are passed through compost filled biofilters (at PWC Pearl commercially available Biocubes® were used). As air moves through the compost, resident bacteria capture and degrade hydrocarbons and hydrogen sulfide. This technology was first evaluated using the 75-liter reactor in preliminary studies conducted by NFESC. It is also employed commercially to control odors at sewage treatment plants, and industries that emit biodegradeable volatiles, e.g., paint spray booths.

At the end of a reaction cycle (about 10 days), the aeration system and recirculation pump are turned off and the solids allowed to settle. After settling, the supernatant is passed through the ultrafiltration unit and an upstream bag filter. Suspended solids (primarily biomass) are recycled back into the reactor. Clean effluent from the ultrafiltration unit is sent to a holding tank (T3) and either discharged to the sewer or used as make-up water. Comprehensive analyses are conducted during SBR operation and prior to the release of solids and permeate.

Retention time in the reactor is determined by the time required for degradation. In a 10,000-gallon reactor with an average retention time of 10 days, the daily (8 hours operation) flow through the ultrafiltration module would be 2,000 gallons. Ultrafiltration effluent includes concentrated solids (primarily biomass) part of which will be recycled back into the reactor. The remaining concentrated solids can be sent to the receiving tank (T1) or SBR tank (T2) prior to being sent to the Landfarm facility at Barber's Point. Clean effluent from the ultrafiltration unit is sent to another holding tank (T3) and either discharged to the sewer connection or used as make up water for raw sludge. Prior to being released the contents of tanks T2 and T3 will be analyzed.

It is most cost effective if the reactor is assembled on-site using commercially available components. Following assembly, the reactor will be operated without sludge to ensure that there are no leaks and that all components are functioning properly. Once the reactor is functioning properly, it will be used to determine the maximum hydrocarbon loading that can be degraded within the designed retention time of 5 to 10 days. It is anticipated that this requires 6 to 9 months during which the critical operating parameters (hydrocarbon loading, concentration of nutrients, and percent biomass recycle) will be systematically optimized. This phase will be guided by performing laboratory studies and using data generated from bench-scale (75 liter) studies. Data collected from ongoing operation of the reactor at PWC Pearl Harbor will also be used to guide the design, purchase of components, and operation of reactors installed at participating activities.

At NAVSTA Pearl Harbor, disposal of biosolids that accumulate in the reactor (T2) is accomplished through landfarming at a Navy owned facility, which is an integral aspect of the project. The landfarm is permitted to take the biosolids along with other liquid oily waste streams. When landfarming or other method (e.g. composting) *is not* an option, biosolids from the reactor will be processed through a filter-press or captured in a bag filter, analyzed, and disposed in a conventional landfill. A summary of the sampling, analyses, and monitoring that may be conducted on the system and its residuals from the SBR is shown in **Table 1.**

Table 1. Sampling, Analyses and Monitoring of the SBR

Parameter	Bioreactor			Landfarm	Method
	Oily Sludge	Ultrafiltrate liquid phase	Ultrafiltrate solids		
Hydrocarbons	Weekly Samples			Beginning and completion of landfarming	8015M and 4030
Biological Oxygen Demand (BOD)	Weekly Samples			Not done	Standard Method 5210 A
Chemical Oxygen Demand (COD)	Weekly Samples				Standard Method 5220 D
Total Suspended Solids (TSS)	Weekly Samples				Standard Method 2540 D
pH	pH electrode for continuous monitoring			Beginning and completion of landfarming	Calibrated pH Electrode
Total Nitrogen	Weekly Samples				Kjeldahl Digestion
Phosphate Nitrate and other anions	Weekly Samples				Ion Chromatography Standard Method 4110 B
Metals	Weekly Samples				Standard Method 3120 B ICP
Temperature	Thermocouple for continuous monitoring			Not done	Calibrated Thermocouple
Fecal coliforms	Not done			Not done	Standard Method 9221 C
Total Volatile Suspended Solids	Weekly Samples			Not done	Standard Method 2540 E

If bioreactor amended landfarm soil does not meet current quality criteria or permit requirements, landfarming will either be discontinued or the biosolids will be filter pressed and landfilled. However, the low levels of hydrocarbons and metals are not expected to impact landfarming quality

3.0 SYSTEM PERFORMANCE

In collaboration with Public Works Center (PWC) Pearl Harbor, NFESC installed and successfully tested a pilot sequencing batch reactor (SBR) capable of treating 3,000 to 4,000 gallons of raw oily sludge per month at PWC Pearl Harbor. To achieve the high bacterial densities that promote rapid biodegradation, and eliminate the need for a clarifier, the system uses an ultrafiltration module to concentrate and recycle bacteria. This innovative use of an ultrafilter allows a 3 to 4 fold reduction in the size of the SBR (**Figure 1**). Another unique aspect of this approach is that the biomass, which accumulates in the reactor, is landfarmed. The biomass is sent to the Barbers Point Biosolids Landfarm Facility operated by PWC Pearl Harbor. The clean liquid stream (permeate) that passes through the ultrafilter is a dilute solution of inorganic nutrients which is either discharged to the sewer or used to dilute incoming oily waste prior to charging the reactor. This unique approach eliminates the need for disposal at landfills and results in complete degradation of hydrocarbons and other organic components in the sludge, leaving only process water and biomass as non-toxic byproducts. To date the SBR has successfully treated more than 40,000 gallons of oily sludge from SBR treatment system and the shipyard oilywaste holding tanks. The 10,000 gallons SBR system at NAVSTA Pearl Harbor is shown in **Figure 2.**

Figure 2. Oily Sludge Bioreactor at NAVSTA Pearl Harbor, HI.
From left-to-right are the control room and blower facilities, biocubes, ultrafiltration module, reactor, and tanks for receiving sludge and storing ultrafiltrate permeate.

The typical practice is to ship the oily sludge to the mainland at an average cost of $0.76/lb. In contrast, on-site biological treatment cost $0.08/lb (actual Hawaii costs) which includes operational and maintenance (O&M) as well as equipment depreciation cost. Thus, biological treatment results in a cost savings of about 90 percent, and eliminates liability of the treated product.

4.0 CRITERIA FOR QUALIFICATION

Economic feasibility, design considerations, regulatory requirements, generation rates, sludge transporting requirements and site applicability are factors that need to be assessed prior to the procurement and installation of a SBR treatment system.

5.0 ECONOMIC FEASIBILITY

Economic considerations are essential to determine the cost-benefit of a system. Since capital investment is required, it is necessary that the system can recover the capital cost and all associated operations and maintenance costs.

Activities that generate and dispose greater than 200,000 pounds of sludge per year at disposal cost of greater than $0.50/lb would benefit from the system. Additional benefits include elimination of liabilities for storing and transferring of this (sometimes) hazardous waste. The system will have a payback of less than three years considering the application just mentioned. An economic analysis (Excel) template for determining the savings to investment ratio (SIR) of employing the system is shown in **Appendix A**.

The results of a Cumulative Net Present Value (NPV) cost analysis for the disposal of 200,000 pounds of oily sludge per year for 10 years is presented here.

Assumptions: Discount rate – 4 percent
Economic Life - 10 years

Cumulative NPV of current disposal method:	$1,541,071
Cumulative NPV of SBR treatment system:	$854,549

OR

Annual Cost of contractor disposal:	$130,000
Annual Cost of SBR treatment:	$80,700

As illustrated by this economic analysis, the procurement of a SBR system for treating oily sludges, versus contractor disposal, is approximately 50% less expensive. Using the contractor disposal cost as a basis, the cost avoidance will pay for the system at NAVSTA Pearl Harbor in 2 years. Note that implementation costs will vary from one activity to another. Generally, SBR treatment system implementation is less expensive than contractor disposal fees.

Other economical considerations that should be addressed are waste characterization and waste generation. Waste characterization is a critical element in the selection of a SBR treatment system. It will identify the contaminants and concentrations of the oily sludge. Furthermore, it will determine whether a SBR system has the capability to treat the oily wastewater and meet discharge standards at the selected site. In most cases, the SBR system can be tailored to meet site-specific parameters and can be designed to treat various contaminants in the influent.

Waste generation is another criteria. Frequency and duration of maximum and average flows must be determined. This will define the size of the system. It is noteworthy that the most effective systems require significant oily sludge generation. Small quantity generators should consider other alternatives as it is unlikely that capital costs for site preparation, equipment costs, and installation costs can be recovered. It is advised that a cost analysis for each specific site be conducted. In addition, each site will have varying elements to be addressed and may play a critical role in determining the viability of SBR treatment system to each individual site. A typical equipment and annual operational and maintenance (O&M) costs for the 250,000 pound system in Hawaii is presented in **Table 2.**

Table 2. System: Sludge Biological Reactor (250k-lb/yr)-Typical Costs

Item	Units	Unit Cost (2001$)	# Units	Total Cost
Capital Costs (Estimated)				
Tank SBR (20k Gallons) w/ Aerators	ea	$21,000	1	$21,000
Receiving Tank (10k Gallons)	ea	$13,000	1	$13,000
Ultrafiltration System,	ea	$45,000	1	$45,000
Blowers	ea	$1,200	2	$2,400
Chemical Feed System	ea	$900	2	$1,800
Biofiltration (carbon filter drum)	ea	$7,000	1	$7,000
Level Sensors & Meters	ea	$1,400	3	$4,200
Control Panel	ea	$7,000	1	$7,000
Piping Material	ea	$12,000	1	$12,000
Valves	ea	$3,000	1	$3,000
Electrical	ea	$3,000	1	$3,000
Secondary Containment	ea	$15,000	1	$15,000
Contingencies/Misc.	ea	$10,000	1	$10,000
Shipping Cost	ea	$6,000	1	$6,000
Total Equipment Cost				$150,400
Installation Cost (30% of capital costs)				$45,120
Total Installed Cost				**$195,520**
Item	Units	Unit Cost	# Units	Cost
Electricity	KWhr	$0.120	20,000	$2,400
Water & Sewer	3600 gal	$15.00	24	$360
Biomass Disposal	ea	$600	6	$3,600
Nutrients	ea	$2,500	1	$2,500
Operating Labor	hr	$50	400	$20,000
Plant Overhead (105% of labor)	hr	$50	420	$21,000
Maintenance (3% of capital investment)	ea			$5,866
Total Annual Cost				**$55,726**
Cost by Single Line Depreciation (SLD)				
Capital Cost	O & M Cost	Salvage Value		Yearly by SLD
$195,520	$55,726	$0		**$75,278**
Cost per Pound[a]				**$0.084**

(a)-Note: The disposal fee of $0.76 per pound is based on large quantities of sludge disposed through DRMO and shipped to mainland. It is currently the average sludge disposal fee. Disposal fees can range from $0.10 to $1.50/lb. This fee varies significantly and does not include storage (e.g., labor and cost of drums) or management cost.

6.0 REGULATORY REQUIREMENTS

Check your local regulatory agency or current waste disposal record to determine if your source of oily sludge is hazardous waste or not. In California for example, oily sludge is presumed to be a hazardous waste unless it is determined pursuant to 66262.11 of the California Code of Regulations (CCR) that it is not a hazardous waste (Note: SBR treatment system renders the sludge non-toxic and non-hazardous).

The SBR system produces three distinctly different wastestreams (biomass, water, and VOC). Biomass accumulates in the SBR tank and receiving tank which occasionally must be disposed approximately twice a year. At NAVSTA Pearl Harbor, these tanks are pumped out using vacuum trucks and the biomass (waste) is disposed to the former NAS Barber's Point. The biomass contains some residual oils, small quantity of metals, and solids. The levels are below TCLP limits for solids and hydrocarbons and in most cases can be safely discharged to landfills. These constituents must be sampled and tested prior to disposal.

The clean water effluent or product can usually be recycled back into the system (to help dilute incoming sludge) and at times discharged into sanitary sewer system. The clean water effluent will meet the most stringent sanitary sewer discharge limits.

Compliance to National Ambient Air Quality Standards (NAAQS) should also be considered. NAAQS sets the minimum standards for air quality across the United States. Commonly, specific limits for states and local areas are more stringent than federal guidelines. The SBR treatment system produces some VOC which is filtered through the system's biocubes. The amount of VOC is usually small compared to the total allowed for the entire facility.

Implementation of secondary containment for the SBR treatment system is required to safeguard local waters and land adjacent to the site. Emergency shower and eye-wash stations must be installed and available within easy reach from chemical systems (see Command's safety rules).

It is advised to consult with applicable local agencies such as the Department of Health Services, City, and Fire Department at each prospective site to determine applicable regional or local standards. There may be specific requirements that the prospective SBR treatment system must meet prior to its installation.

Each activity will be required to obtain all necessary permits to operate the system. This includes local, state, and federal regulatory permits where they apply. NFESC will assist in the acquisition of the permits when done at the start of the project.

7.0 INSTALLATION CONSIDERATIONS

Installation of the SBR treatment system must take into considerations the following: location, generation rates, transportation, available equipment, utility hook-up/availability, and personnel operation skills.

Each prospective site is required to provide an oily sludge receiving tank along with the necessary pumping station required. The size of the receiving tank and the type of the system is dependent on the oily sludge generation rate at the prospective site.

Oily sludge generation rate is estimated by accounting for the volume of oily waste (e.g., bilge water) treated at a facility and multiplying this amount by 2 percent. For example, processing 100,000 gallons of bilge water or similar oily waste will generate approximately 2,000 gallons (18,000 pounds) of oily sludge.

Other special considerations should include:

- **Freeze Protection:** Since the system employs biological treatment, its performance is related to temperature and environment. If necessary, a building enclosure must be provided to prevent liquid from freezing to keep the bacterial bugs happy. For design criteria in cold regions, refer to Department of Army Corps of Engineers, TM 5-852, Series on Arctic and Subarctic Construction.

- **Disposal of biomass:** Ideally the biomass could be disposed at a government owned landfarm. If this is not practical or available, the system can include a filter press to concentrate the biomass and solids to a compact size for disposal as a regular solid waste.

Oily sludge may be off-loaded from different activities or sludge generators usually by tank trucks and in some cases delivered in 55-gallon drums. Oily sludge transporting will vary from site to site and will be dependent on the resources available at a given site. A vacuum truck or double diaphragm pump can be used to move the oily sludge. In some cases it may be necessary to wash down the sludge with water to break down extra heavy sludge.

7.1 Site Considerations

Site designation for the SBR treatment system is vital. It will define implementation costs, as well as determine whether the site is suitable for implementation. Key elements are that the site be located within the proximity of readily available utilities such as electricity, water, potable water, and, if possible, compressed air. A nearby oily waste treatment facility is also an important factor to take advantage of permitting and personnel issues.

Site preparation costs will vary from site to site depending on accessibility, tanks availability, secondary containment, building enclosure requirements, and use of existing facilities. Secondary containment must be able to contain the volume of the largest tank plus the amount of the maximum rainfall for a 25-year, 48-hour storm. The secondary containment pad should also be able to handle the weight of the heaviest tank when completely full.

The common utility requirements for a 200,000 pound/yr capacity SBR system are: electricity (100 amp, 480 VAC, 3 phase), water line, sewer connection, phone line (optional), and a layout area of approximately 2,000 square feet. The water supply line must be equipped with a back-flow check-valve to prevent any contaminants inside the secondary containment from entering the city water supply line.

A 1-year supply of the nutrients and chemicals required for the system should be provided. NFESC or the proposed contractor can assist the activity in setting up the procurement of materials through the activity's procurement/supply office. Training of facility personnel and management should be provided.

7.2 Staffing Considerations

Designation for SBR treatment system operation and maintenance personnel will be at the discretion of the prospective site's management. It is recommended that candidates for SBR treatment system implementation should have a basic knowledge of wastewater treatment and the knowledge and skill to operate an industrial system of this scale.

All selected personnel involved in operating the system will be instructed verbally, as well as hands-on training. Instruction will take approximately one week. Manuals shall be prepared for start-up, operation, shut-down, and maintenance of the system.

Each prospective site may require specific instruction depending on the design configuration of the system. However, the system is fully automated and requires minimal attention. The SBR treatment system is equipped with automated controls and sensors integrated into the system. This simplifies its operation and prevents spills due to equipment failure. In addition, all chemical additions are automated.

8.0 DESIGN CRITERIA

SBR treatment system design is specific for each prospective site. The SBR is custom tailored to suit the installation's specific waste characterization and quantities generated. The integrated system is designed based on a treatability study of the prospective site. Analysis will determine specific process equipment, such as the use of ultra-filtration (UF) unit and filter press unit.

The time estimate for system installation is approximately 20 months. Three to four months are required for the system design and site preparation work (utilities installation,

berm, etc.). Another 8 to 9 months are for contract award, procurement and installation. Initial loading and operational testing will run another 4 to 6 months. User's training will be performed during and at the end of system testing. This time frame is critical to accurately design a system that meets a prospective site's specifications. The contractor (or NFESC) coordinates all design efforts with the proposed site's personnel to ensure the product is delivered on time, within budget, and with customer satisfaction.

9.0 EXAMPLE OF A STATEMENT OF WORK

Generally, there are two statements of work (SOW). One focuses on the specifications for site preparation, the other focuses on the specifications for the installation of the SBR treatment system equipment.

The SOW for an actual system installation and site preparation is very site specific and may consists of volumes of data. An example of a statement of work for system installation and operational testing is included in **Appendix B**. A package of information (containing system schematics, equipment and material listing) for system installation of the SBR system in Hawaii is included in **Appendix C**. The SOW in **Appendix B** is written as an example of the system purchased for NAVSTA Pearl Harbor, and, as such, can be used for the model of a system purchased at another site. The SOW is written as if a contractor performs the work although at NAVSTA Pearl Harbor the majority of work was performed by NFESC for this demonstration project. An activity considering this type of work is welcome to consult with NFESC to determine the best option for that activity to proceed in terms of maximizing and leveraging any Navy funds available before committing to a course of action.

APPENDIX – A

SAMPLE – ECONOMIC ANALYSIS

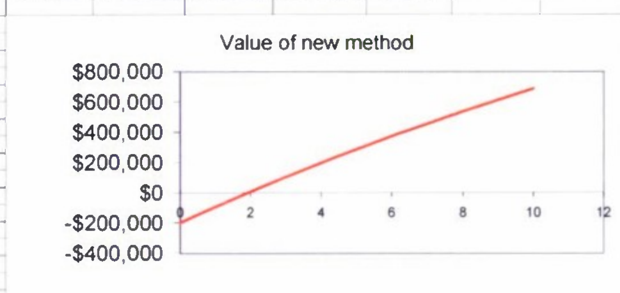
Economic Analysis

Oily Sludge Pearl (250,000lb/yr)

Instructions: Fill in the data in the grey shaded cells. Costs are negative and income is positive.
Year 0 is when investment in new project is made. Year 1 is one year later. year 2 is two years later. etc.
If you are comparing two alternatives (instead of comparing an alternative to the status quo), input the captital cost of Alternative A into cell D12.

1.00	Current method								lb/yr =	250000.00	$/lb =	-0.76	
	Year		0	1	2	3	4	5	6	7	6	9	10
1.10	Expenses												
1.1.1	Capital cost		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.1.2	labor												
1.1.3	materials												
1.1.4	energy			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.1.5	other	HW disposal		-190000.00	-190000.00	-190000.00	-190000.00	-190000.00	-190000.00	-190000.00	-190000.00	-190000.00	-190000.00
1.20	Income			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	New method (SBR)			In-ground storm water filter									
	Year		0	1	2	3	4	5	6	7	6	9	10
2.10	Expenses												
2.1.1	Capital cost		-200000.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.1.2	labor	O&M		-47000.00	-47000.00	-47000.00	-47000.00	-47000.00	-47000.00	-47000.00	-47000.00	-47000.00	-47000.00
2.1.3	materials	filter media/nutrients		-2500.00	-2500.00	-2500.00	-2500.00	-2500.00	-2500.00	-2500.00	-2500.00	-2500.00	-2500.00
2.1.4	Utilities	electric&water		-27600.00	-27600.00	-27600.00	-27600.00	-27600.00	-27600.00	-27600.00	-27600.00	-27600.00	-27600.00
2.1.5	Disposal	Biomas&Sewer		-3600.00	-3600.00	-3600.00	-3600.00	-3600.00	-3600.00	-3600.00	-3600.00	-3600.00	-3600.00
2.20	Income				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
				-80700.00	-80700.00								
3.00	Interest rate		4.00	%	(use 10 year Treasury bond yield)								
4.00	Present worth												
	Year		0	1	2	3	4	5	6	7	8	9	10
4.10	Current method		0.00	-182692.31	-175665.68	-168909.31	-162412.80	-156166.15	-150159.76	-144384.36	-138831.14	-133491.46	-128357.19
4.20	New method		-200000.00	-77596.15	-74611.69	-71742.01	-68982.70	-66329.52	-63776.38	-61325.37	-58966.70	-56698.75	-54516.03
4.30	Net present worth of current method				-1,541,070.20								
4.40	Net present worth of new method				-854,549.29								
	New project is viable if net PW of new method is greater than net PW of current method												
5.00	Savings to investment ratio			SIR =	3.43								
	Year		0	1	2	3	4	5	6	7	8	9	10
6.00	Present worth of savings		-200000.00	105096.15	101053.99	97167.30	93430.10	69838.63	86381.38	83059.02	79864.44	76792.73	73839.16
	Year		0	1	2	3	4	5	6	7	8	9	10
7.00	Value of new method		-200000.00	-94903.65	6150.15	103317.45	196747.55	286584.16	372965.56	456024.56	535889.01	612681.75	686520.91

Payback occurs in year when value of new method goes from negative to positive



8.00	Internal rate of return												
	Trial value of interal rate of return =			415.00	%								
	Pick values of internal rate of return (cell E73) such that net (cell D80) equals zero.												
	Internal rate of return must be greater than the cost of money for project to be viable												
	Year		0	1	2	3	4	5	6	7	6	9	10
8.10	Current method		0.00	-36893.20	-7163.73	-1391.02	-270.10	-52.45	-10.16	-1.98	-0.38	-0.07	-0.01
8.20	New method		-200000.00	-15669.90	-3042.70	-590.82	-114.72	-22.28	-4.33	-0.84	-0.16	-0.03	-0.01
8.30	Difference		-200000.00	21223.30	4121.03	800.20	155.38	30.17	5.86	1.14	0.22	0.04	0.01
8.40	Net		-173662.65										

APPENDIX – B

SAMPLE – STATEMENT OF WORK

Statement of Work

Month dd, year

BIOLOGICAL TREATMENT SYSTEM FOR OILY WASTE SLUDGE
for
NAVSTA Pearl Harbor

1.0 WORK SCOPE

1.1 BACKGROUND. The Naval Facilities Engineering Service Center (NFESC) has developed a process to bioremediate oily sludge from tank bottoms, bilge oily waste treatment facilities, and the automotive industry through the use of membrane bioreactors. NFESC laboratory research concluded that bacteria already present in and adapted to oily sludge from a variety of sources degrade the hydrocarbons found in oily sludge within 2 weeks from 20,000 ppm to less than 100 ppm. In addition, the concentrations of heavy metals (primarily zinc and copper) and total suspended solids in treated sludge residuals remain well below discharge limits. These results demonstrated that on-site biological treatment was technically and economically feasible.

Membrane bioreactors are conventional bioreactors that use an ultrafiltration module to concentrate and recycle bacteria to achieve high bacterial densities essential for rapid biodegradation. A major advantage of this approach is the reduction in size of the reactor by as much as a factor of five. To have on-site oily sludge treatment capabilities, NAVSTA Pearl Harbor in collaboration with NFESC will install a sequencing batch reactor (SBR) with ultrafiltration membrane bioreactor at NAVSTA Pearl Harbor.

1.2 SCOPE. Contractor shall design, procure, install, test and start-up the SBR with UF bioreactor as specified in this document. In addition, the contractor shall provide user's training, and update the existing Operational and Maintenance (O&M) manual to include equipment list (manufacturer, model #, part #) and cost. The contractor shall integrate the upgraded hardware into the system and as necessary upgrade the operating system software to accommodate the upgraded hardware.

The contractor shall:

Design, procure, and install the SBR system as specified below. The system shall be fully automated using the latest Allen Bradley control technology. The Ultra-filtration component specifications are provided below:

- ASME rated fiberglass spiral wound membrane housings
- Osmonics AG-8040F Filter Elements
- Ultrafiltration recirculation loop
- 7.5 hp Gould SST 5 micron pressure pump

The contractor shall make all necessary modifications to any existing tanks in order to facilitate its usage as a sequence batch reactor in accordance with the schematic.

The contractor shall provide a transfer system to include cam-lock coupling, piping, check valve, and alarm horn / light for the unload of trucks at the SBR. Additionally, contractor shall provide an air compressor, sun shield (control center), and any modifications necessary for the treated water storage tank. Contractor shall complete the system installation, provide operations manuals, and system training (2 days) for the operators. In summary, contractor shall deliver a turnkey SBR system to include an ultrafiltration system.

1.2.1 Size and Capacity of SBR System

The proposed SBR system is shown in Figure 1 of the UDP. The reactor tank (T2) has a working capacity of 9,000 gallons and a nominal design capacity of 15,000 to 20,000 gallons per month of diluted sludge, which corresponds to 3,000 to 4,000 gallons per month of raw oily sludge. Oily sludge generation rate is estimated by accounting for the volume of oily waste (e.g. bilge water) treated at a facility and multiplying this amount by 2 percent. For example, processing 100,000 gallons of bilge water or similar oily waste will generate approximately 2,000 gallons (18,000 pounds) of oily sludge.

1.2.2 Performance Criteria of SBR System

The SBR process, system performance, and data results are presented in TECHNICAL REPORT TR-2229-ENV, "OPERATIONAL TEST REPORT (OTR): ON-SITE DEGRADATION OF OILY SLUDGE IN A TEN-THOUSAND GALLON SEQUENCING BATCH REACTOR AT NAVSTA PEARL HARBOR, HI", NFESC, November, 2003, Sonny Maga et al.
The proposed SBR system shall meet similar performance criteria. A summary of significant performance results are as follows:

- Currently, a degradation cycle requires 5 days. The recirculation pump is turned off and the solids allowed to settle. The ultrafiltration unit requires approximately 16 hours to process the contents of the reactor.

- The concentration of hydrocarbons in the sludge in the reactor (after steady state operation) was less than 500 ppm. That was well within the allowable concentration for disposal at the landfarm.

- Copper, nickel, and zinc are the predominant metals that accumulate in the reactor at non-hazardous levels, which is consistent with the origins of the sludge. Lead, chromium, and cadmium were not detected in the liquid phase.

- To minimize (eliminate) the emission of priority pollutants (**B**enzene, **T**oluene, **E**thylbenzene, **X**ylenes (BTEX)), exhaust air from the SBR is passed through

compost biofilters (Biocubes). Biofilters routinely remove more than 90% of BTEX from contaminated air. When biodegradation in the SBR (measured >99.5%) is included, total yearly emissions of BTEX are predicted to be less than 16 pounds per year.

- Samples of raw and treated sludge were assayed for toxicity. While raw sludge was toxic in both assays, treated sludge was not toxic in either assay.

1.2.3 Operations and Maintenance Manual. The contractor shall update the O&M manual for the Pearl Harbor bioreactor. The manual shall consist of all equipment drawings, manuals and warranties supplied by the vendors/manufactures description equipment list (manufacturer, model #, part # and cost) of all equipment used in the treatment system. The manual shall also address lubrication, adjustments, and maintenance for all equipment as provided by the manufactures. The manual shall have a section for start-up, shutdown, and troubleshooting and be submitted in (3) hard copies.

1.2.4 Shipping. The contractor shall ship all necessary equipment and material via commercial ocean freight, to the following address:

Navy Public Works Center
Environmental Department, Code 342
Building 1910, Sixth Street
Pearl Harbor, HI 96860

1.2.5 Government Furnished Material/Facilities Requirements: The government will provide utilities to the site, fork-lift, and cranes as necessary. The common utility requirements for a 200,000 pound/yr capacity SBR system are: electricity (100 amp, 480 VAC, 3 phase), water line, sewer connection, phone line (optional), and a layout area of approximately 2,000 square feet. The water supply line must be equipped with a back-flow check-valve to prevent any contaminants inside the secondary containment from entering the city water supply line. The government will provide checks to existing tanks for gas-free conditions prior to contractor doing any work.

Contractor shall supply all other services, labor, materials, and equipment necessary to perform this effort.

1.2.6 Functional/Operational Requirements: Contractor shall insure that all equipment is properly installed, operational and that the systems have been hydraulically tested for leaks and tagged as necessary for safety requirements.

2.0 DELIVERABLES/END PRODUCTS

The deliverables consist of the complete installation of the hardware so that the system is ready for operation and testing. Technical data (O&M manual) is due upon completion of the installation and approved by NFESC for NAVSTA Pearl Harbor. Three copies of the

O&M manual shall be provided as specified in Section 1.2.3. Training of two days duration shall be provided as specified in Section 1.2.

3.0 PROJECT MANAGEMENT

The Contracting Officer Representative (COR) is Mr. (Name: COR). The sponsor and ultimate customer for this work is Naval Station Pearl Harbor, Public Works Center. The Environmental Program Management is under the direction of the Technology Implementation and Customer Liaison Office (ESC45). Resource management for this project is under the Director of the Pollution Prevention Division (ESC42), as assigned to the Project Engineer and Navy Technical Representative, Mr. (Name: NTR/Project Engineer, ESC421).

4.0 SCHEDULES

The total time to install and test the system shall be 8 months from date of contract award.

4.1 Schedule of Deliverables

Operational and Maintenance (O&M) Manuals shall be provided within 9 months from date of contract award.

4.2 Period of Performance

The overall installation, testing and start-up of the oily sludge bioreactor shall be accomplished within 9 months from date of contract award.

5.0 TRAVEL

Travel from Port Hueneme, CA, will consist of three trips to NAVSTA Pearl Harbor for initial site assessment (2 days), onsite fabrication and equipment installation (14 days), and training (1 day). It is anticipated this efforts will consist of 2 to 4 personnel.

6.0 INSPECTION AND ACCEPTANCE

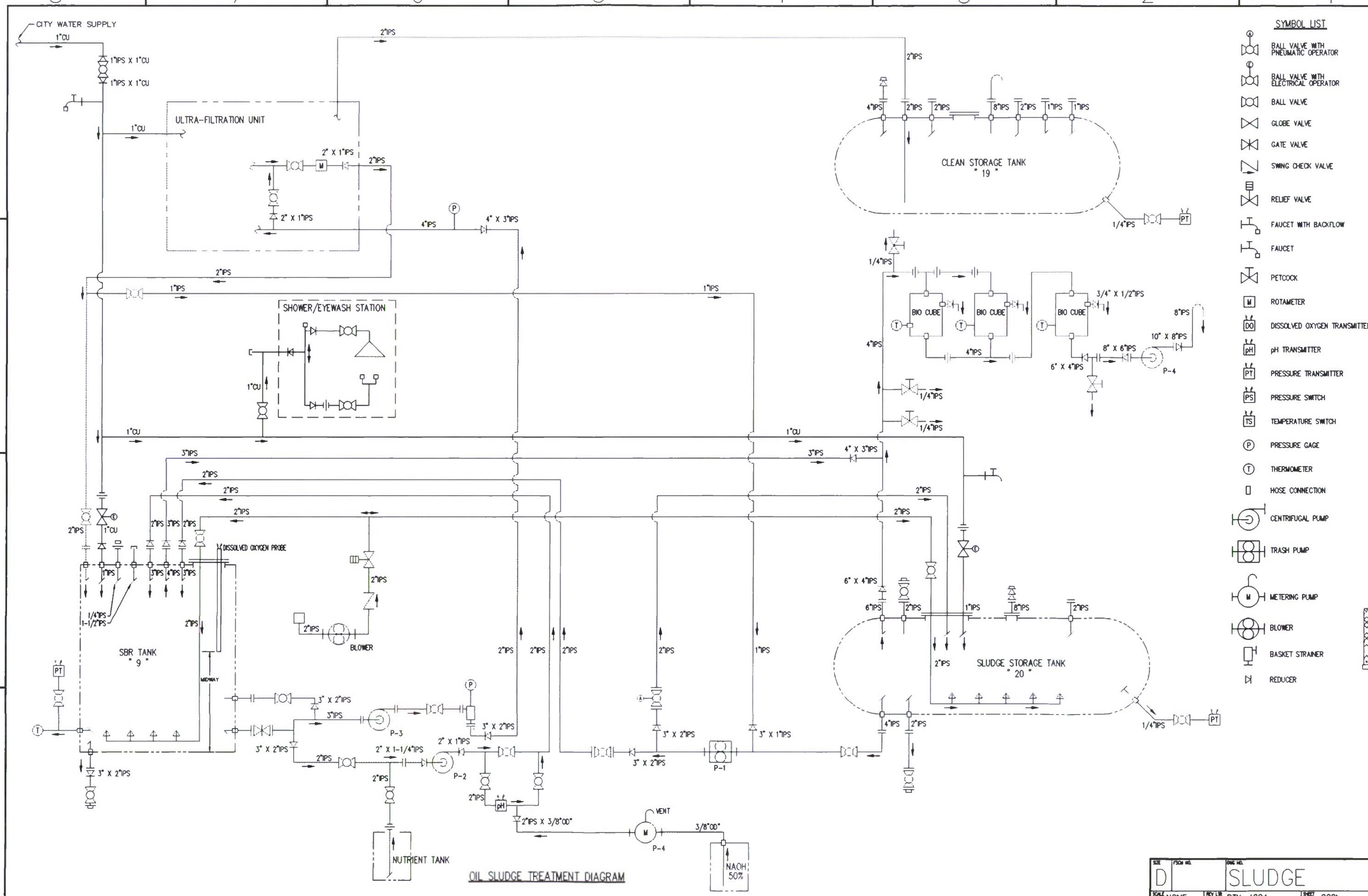
Inspection and Acceptance shall be performed at the bioreactor and ultrafiltration/reverse osmosis sites. Inspection shall be performed by the NFESC project engineer and acceptance shall be performed by the assigned COR, phone (XXX) xxx-xxx, with recommendation from the Navy Technical Representative, Code ESC 421, phone (XXX) xxx-xxxx.

6.1 Acceptance Criteria

The proposed SBR system shall meet or exceed the performance criteria as specified in this SOW, section 1.2.2. Any deviations of the performance criteria, based on actual site variations, environmental limits, or unforeseen circumstances, may be approved by the personnel in Section 6.0.

APPENDIX – C

AUTOCAD DRAWINGS



OIL SLUDGE TREATMENT DIAGRAM

VALVE IDENTIFICATION:

4" UE BALL VALVE	V1705	(V1)	UF INFLUENT
1" UE 3-WAY BALL VALVE	V1707	(V4)	UF PERMEATE / WASH RETURN
TEMPERATURE SWITCH	V1707	(TS1)	UF PERMEATE / WASH RETURN
1" UE PINCH VALVE	V1708	(V10)	UF PERMEATE THROTTLE
3" UE BALL VALVE	V1709	(V9)	UF CONCENTRATE ISOLATION
2" UE PINCH VALVE	V1710	(V5)	UF CONCENTRATE THROTTLE
3" UE BALL VALVE	V1711	(V7)	UF 8YPASS
1" UE 8ALL VALVE	V1713	(V6)	UF INFLUENT EXTERNAL DRAIN
3" UE BALL VALVE	V1714	(V3)	UF WASH RETURN ISOLATION
2" UE BALL VALVE	V1731	(?)	T-31 EXTERNAL DRAIN
4" UE BALL VALVE	V1732	(V2)	UF WASH SUPPLY

QUADPACK:
EG & G BIOFILTRATION
BIOCUBE
AEROBIC BIOFILTER
NORTH ST
SAUGERTIES, NY 12477
(914) 246-3401

MODEL: N-X039075
SERIAL NO.: IG 00094
MAX FLOW: 150 CFM
MAX STATIC VACUUM: 60" H20
MAX TEMP: 130F

COMPRESSOR:
DAYTON AIR COMPRESSOR
DAYTON ELECTRIC MFG CO.
NILES, IL 60714
MODEL: 5Z634, 2 STAGE, CCW ROT, 25 HP, 3 PHASE
SERIAL NO.: 112995L-798580

MOTOR:
US ELECTRIC MOTOR
DIVISION OF EMERSON ELECTRIC CO.
ST. LOUIS, MO

MODEL: J141A, HP: 25, PH: 3, HZ: 60
FRAME: 284T, TYPE: 0 ENCLOSURE, SF: 1.1S
ID#: Y09Y208R055R-16, CODE: H, DES: A
VOLTS: 208/230/460, RPM: 1770, INSUL CLASS: F
AMPS: 68/62/31
MAX AMB: 40C, DUTY: CONT
SF AMPS: 80.5/71.6/35.8
NEMA NOM EFFICIENCY: 89.S
LOW SHAFT END BRG: 6310-2Z-JC3
UPPER OR OPP END BRG: 6130-2Z-JC3
CUSTOMER PART NO.: MC301502AV

SILENCER:
UNIVERSAL SILENCER
DIVISION OF NELSON INDUSTRIES, INC.
PO BOX 411
STOUGHTON, WI 53589

MODEL NO.: CCS-2
PART NO.: 34-202-AA
SERIAL NO.: B4155-96
PAPER: 81-0471
FELT: 81-1203
WIRE MESH: 81-1036

PUMP:
SUTORBILT
MODEL NO.: GABMDPA
CATALOG NO.: 3MP
SERIAL NO.: S107398
MAX RPM: 3600
POSITIVE DISPLACEMENT LOBE BLOWER/VACCUM PUMP
GARDENER DENVER BLOWER DIVISION
160 GARDENER PARK
PEACHTREE CITY, GA 30269 (770) 632-5000

MOTOR:
BALDOR INDUSTRIAL MOTOR
BALDOR ELECTRIC CO.
FT. SMITH, AR

CAT NO.: M3710T
SPEC: 37G813Y659H1
HP: 7-1/2
VOLTS: 230/460
AMPS: 20.4/10.2
RPM: 1780
FRAME: 213T, HZ - 60, PH - 3
SERF: 1.15, CODE: J, DES: B, CLASS: F
NEMA NOM EFFICIENCY: 83.S%, PF: 76%
RATING: 40C, AMB: CONT
BEARING DE: 6307
ODE: 6206
ENCL: TEFC
SERIAL NO.: F0106271465

IWAKI EH CONTROLLER:
MODEL EHC: B11UPY
VOLTAGE: 115
MFG NO. : 1190226

IWAKI METERING PUMP:
CAPACITY: 1.0 GPH
MAX PRESS: 105 PSI
STROKE RATE: 0 - 360 SPM
VOLTAGE: 11S V
CURRENT: 0.9A
THERMALLY PROTECTED
FREQ: 50/60 HZ
MODEL: EHB15Y1-PE

PRE-FILTER PUMP:
G & L PUMP
SIZE: 2" X 2-1/2"-6
CAT NO.: 6STK2
IMP DIA: 4-9/16", A9512408

MOTOR:
BALDOR INDUSTRIES MOTOR
CAT NO.: JMMS709T
SPEC: 37M31X7S
FRAME: 213JM, SER: F495
HP: 7-1/2 TE
VOLTS: 208-230/460
AMPS: 21-18.6/9.4
RPM: 3450
HZ: 60
SER F: 1.15
PH: 3
CLASS: F
DES: 8
CODE: J
NEMA NOM EFF: 84%
PF: 90%
RATING: 40C
AMB: CONT

NUTRIENT PUMP:
G & L PUMP
MODEL: NPO
CAT NO.: 1SN1F5C4
SIZE: 1" X 1-1/4"-6
IMP SIZE: 3-3/4"

MOTOR:
FRANKLIN ELECTRIC
BLUFFON, IN 46714 USA
MOD: 1313480103
HP: 1/2, RPM: 3450
VOLTS: 208-230/460
FLA: 4.5-4.8/2.4
SF: 1.3
SFA: 5.4-5.4/2.7
FR: 56T
PH: 3
MAX AMB: 40C
ENC: TEFC
TIME RATE: CONT
KVA CODE: M
DATE CODE: E01

TRASH PUMP:
TEEL
MOD: 3P609B 0502
DAYTON ELEC MFG CO.
NILES, IL 60714 USA

MOTOR:
ENERGY EFFICIENT INDUSTRIES MOTOR
MODEL NO.: 3KV80A, FR: 184T, ENCL: TE
TYPE: FCT, INSUL CLASS: FCT, MAX AMP: 40
% DUTY CYCLE: CONT, PH: 3
SHAFT END BRG: 6206-2ZJC3
OPP END BRG: 6205-2ZJC3
MOTOR REF: B01-T863B-H
USABLE ON 280V 60HZ AT 16.5 MAX AMPS
HP: 5, RPM: 1755
VOLTS: 208-230/460
FL AMPS: 14-12.7/6.35
SF AMPS: 14.S /7.25
SF: 1.15, DESIGN: B, CODE: J
NEMA NOM EFFICIENCY: 87.5, NOM PF: 84.3
GUARANTEED EFFICIENCY: 85.S
MAX KVAR: 1.8

ROTAMETER:
2 - 20 GPM (8 - 80 LPM)
2 GPM MAJOR GRADIENT (8 LPM MAJOR GRADIENT)
1 GPM MINOR GRADIENT (4 LPM MINOR GRADIENT)
BLACK SCALE
1" FPT

pH/ORP CONTROLLER:
GF SIGNET
PART NO.: 3-8750-1P
SERIAL NO.: 60106135327

DISSOLVED OXYGEN ANALYZER:
INSITE IG
MODEL: 1000
115/230 V, 50 WATTS, 50/60 HZ
SERIAL NO.: 10A1077
WWW.INSITEIG.COM (985) 639-0006

PRESSURE GAGE:
0 - 100 PSI
10 PSI MAJOR GRADIENTS, 2 PSI MINOR GRADIENTS
1-1/2" DIA DIAL FACE
BLACK LETTERING WITH WHITE BACKGROUND
BLACK NEEDLE
1/8" MPT, 8ACK CONN

PRESSURE TRANSMITTERS:

WIKA	WIKA
0-100" H20	0-10 PSI
4-20 mAMP	4-20 mAMP
SERIAL NO.: 3180508	SERIAL NO.: 3118369
PART NO.: 8341481	PART NO.: 8642885

STRAINER:
HAYWARD INDUSTRIES PRODUCT, INC.
MAX WP: 150 PSI @ 400oF
MDMT: -20F @ 150 PSI
SERIAL NO.: K990280-20
YEAR BUILT: 2002
PART NO.: TBF0112S802F

SOLENOID VALVE:
ASCO
CATALOG NO.: 8290B010, NC, INLET PORT 2
INLET: 1" NPT, ORIFICE: 1"
MATERIAL: BRONZE
MAIN PRESSURE RATING:
AIR - 150 PSI
LIQUID - 150 PSI
STEAM - 150 PSI
MAX TEMP: 366F
AUX PRESS RATING: 60 - 150 PSI
REBUILT KIT NO.: C131206
SERIAL NO.: 1369792-001

CONTROL VALVE:
SMC
NVV5FS2-01T-041-02T
NVF2100-EFZ
SUPPLY: 0.1-1.0 MPa

PNEUMATIC BALL VALVE:
VALTACO
15166
DN: 50/40
316/1.401
FPT ENDS, FLANGE BODY
STAINLESS STEEL BODY

PCC TECHTORA ACTUATORS
MODEL: TDA8UNC
MAX AIR: 10 BAR / 150 PSI
PART NO.: MEK008B100
SERIAL NO.: 259040
SPRINGS: 0

SIZE	FSCM NO.	DWG NO.
D		SLUDGE
SCALE NONE	REV LTR RTK-5073	SHEET 002b